(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 366 210 A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 89202695.6

(51) Int. Cl.^{5}: B32B 27/32

(22) Date of filing: 25.10.89

(30) Priority: 27.10.88 US 263576

(43) Date of publication of application: 02.05.90 Bulletin 90/18

(84) Designated Contracting States: BE CH DE ES FR GB IT LI NL

(71) Applicant: SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ B.V.
Carel van Bylandtlaan 30
NL-2596 HR Den Haag(NL)

(72) Inventor: Harrison, Ian Roland
1219 Deerfield Drive
State College Pennsylvania 16803(US)
Inventor: Klingensmith, George Bruce
1828 Milford
Houston Texas 77098(US)

(74) Representative: Aalbers, Onno et al
P.O. Box 302
NL-2501 CH The Hague(NL)

(54) High strength high modulus polyolefin composite with improved solid state drawability.

(57) A drawn polyolefin laminate having a tensile strength of at least 0.35 GPa, a 1% secant modulus of at least 10.5 GPa and an elongation at break of less than 10%, and comprising

a) a core layer of a polymer selected from the group consisting of polypropylene and linear low density polyethylene and on each side thereof;

b) a coextruded cap layer of a polymer selected from the group consisting of butene-1 homopolymers and copolymers thereof with ethylene, the laminate having been stretched to a draw ratio of at least 15:1.

EP 0 366 210 A2

HIGH STRENGTH HIGH MODULUS POLYOLEFIN COMPOSITE WITH IMPROVED SOLID STATE DRAWABILITY

Today, in industry there are many engineering plastics with a broad range of properties. For some applications, the engineer may want a combination of properties inherent in several different types of plastics. One way to obtain these different properties is to develop techniques that will combine these materials while maintaining their desirable qualities. Coextrusion of multilayered sheet and film is such a technique. Some of the more desirable material properties are good corrosion, light, or temperature resistance, gas/moisture permeability with organoleptics (aroma/taste barrier properties), high tensile strength, high elongation and desirable electrical properties. It is also a necessary requirement that, after forming, multilayer polymer sheets should not delaminate in use. Good bonding between the two polymers is often achieved by holding them together under pressure in the molten state. This can be accomplished by coextruding the polymer sheet from a single die orifice.

The ultimate theoretical strength properties of polymeric materials are generally calculated based on a state in which the molecules are fully extended and are perfectly aligned and packed to maximize the forces of intermolecular attraction. This ideal condition is never achieved in practice and the properties expressed by a particular fabricated form of a polymeric material are some (usually small) fraction of the theoretical as determined by the extent to which the fully extended, perfectly aligned state is approached under the conditions imposed by the particular method of fabrication. In the case of polyolefins, and specifically for polypropylene, the theoretical modulus is calculated to be about 50 GPa, representing a theoretically achievable draw ratio of around 100. For existing commercial processes, such as that for producing monoaxially drawn strapping tape, ribbon, or fibrillated fiber, operation at economically high rates (> 30 meters/min) with practical feedstocks of conventional types of polypropylene gives rise to draw ratios of 6 to 8 and moduli of 3-3.5 GPa. Attempts to develop higher draw ratios and properties lead to tape breakage and/or fibrillation.

The production of high modulus films and fibers by various methods of deformation of thermoplastics has become commonplace in industry. There are many methods which are currently used for producing high modulus and high strength films and fibers in industry. Deformation processes such as roller-drawing, hydrostatic extrusion, solid state extrusion, gel spinning/hot drawing, superdrawing and zone-annealing have been employed to try and achieve the highest possible strength and modulus. The gel spinning/hot drawing technique currently produces the highest strength and modulus fibers of polyethylene. The moduli of these fibers have been reported to be as high as 120 GPa with a breaking tensile strength just over 4.0 GPa. A similar technique, drawing dry gels crystallized from dilute solution, currently produces the highest strength and modulus polypropylene films with a Young's modulus of 36 GPa and a tensile strength of 1.08 GPa.

Gel spinning and drawing dry gels are excellent methods for producing high strength fibers and films but they have a number of inherent problems. Generally speaking, the techniques are a high technology method requiring specific polymer molecular weights and distributions. In addition, the gel spinning technique requires extensive solvent removal schemes such that the costs for these polyolefin fibers are comparable to acid spun high temperature aromatic

The present invention is concerned with a drawn polyolefin laminate having a tensile strength of at least 0.35 GPa, a 1% secant modulus of at least 10.5 GPa and an elongation at break of less than 10%, and comprising

a) a core layer of a polymer selected from the group consisting of polypropylene and linear low density polyethylene and on each side thereof;

b) a coextruded cap layer of a polymer selected from the group consisting of butene-1 homopolymers and copolymers thereof with ethylene, the laminate having been stretched to a draw ratio of at least 15:1.

The present invention comprises the surprising and unexpected discovery that coextruded laminates as described above exhibit substantially improved drawability in conventional extensional processing, i.e. they can be drawn to much higher draw ratios at much higher draw rates than can monolithic sheets of either polymer. Thus, polypropylene alone exhibits a draw ratio of about 6 to 8 times its natural draw ratio in conventional drawing and polybutene-1 and its ethylene copolymers, because of their pronounced strain hardening characteristics, show even lower limits of 2-3 times. The composites described above are able to achieve draw ratios of greater than 15 times in commercial type equipment at rates regarded as commercially acceptable. In this highly extended state, the composite laminates exhibit tensile strength typically of at least 0.35 GPa (compared to 28-35 MPa for unoriented polypropylene), 1% se-

cant modulus 10.5 GPa (compared to 1.4 GPa for unoriented polypropylene), elongation at break under 10% (compared to 300-700% for unoriented polypropylene) and exceptional creep resistance as exhibited by the low extent of volume swell and radial increase with time and temperature of pressurized cylindrical vessels constructed from the composite laminates. The cap layers preferably comprise from 10 to 20% of the thickness of the composite.

The polybutene cap layers of the 3-ply laminates, because they have a substantially lower melting point than the polypropylene cores, also provide a means to weld multiple plys together at temperatures below which the highly oriented state of the core is adversely affected. A great variety of isotropically strong, high modulus structural, load bearing, pressure containing and anti-ballistic articles can thus be constructed from this material. By mutual mechanical reinforcement an unexpected synergistic mechanical interaction develops when the more drawable polypropylene core in some manner promotes the extendability of the less drawable polybutylene polymer caps, while these caps in some manner convey enhanced extendability to the propylene core. One function of the tough polybutylene polymer layers is to arrest crack initiation and propagation in the polypropylene core and thereby prevent the fibrillar failure that is characteristic of monolithic polypropylene when drawn to high ratios at high rates in conventional processes. Thus, the extent to which the coextruded material can be synergistically drawn is significantly greater than would have been expected based on the responses of the respective components drawn alone.

The materials which can be used as the core layer include polypropylene polymers including substantially crystalline highly isotactic polypropylene, which is preferred and linear low density polyethylene which is actually a copolymer of ethylene and up to 5% of 1-butene. The molecular weights of the polypropylene core polymers (in terms of melt flow, M.F.) may range from 0.1 to 20 M.F., preferably from 0.7 to 5.0 M.F.

The cap layers should be formed of a material which is selected from the group consisting of polybutene homopolymers and copolymers with ethylene. Polybutene-1 is one example of such a material. Other examples include copolymers of butene-1 with ethylene where the ethylene contents range from 0.1% to 10% weight, preferably 0.5% to 6%. Molecular weights of the polybutene polymers (in terms of melt index, M.I.) may range from 0.1 to 1,000 M.I., preferably in the range of 0.5 to 3.0 M.I. It is preferred that the cap layers comprise from 10% to 20% of the thickness of the total composite because the influence by the core polymer on the extendability of the caps diminishes at thicknesses greater than about 20% and because the high modulus properties of the laminate derive mainly from the core which therefore must comprise the major proportion of the structure.

The composites of the present invention have utility in a wide variety of applications. One such application is in the packaging area, for instance, plastic cans. Beverage containers made of the laminates of this invention have excellent resistance to creep. It is also possible to use these highly extended laminates for the repair of existing fracture pipes or for but joints of pipes. The laminate would be spirally wound in opposing directions to extend beyond the presence of the fracture zone or for a reasonable distance on either side of the but joint. These materials could be used for auto bumper systems and a variety of energy absorbing uses such as crash components and anti-ballistic structures.

EXAMPLES

The following coextruded sheet samples were employed in the test using commercial oriented polypropylene equipment:

1. PP(5225)/PP(5225)/PP(5225), 0.076/0.61/0.076 mm
2. PB(8010)/PP(5225)/PB(8010), 0.076/0.61/0.076 mm

PP(5525) = isotactic polypropylene homopolymer of melt flow 0.7,

PB(8010) = 0.6% weight ethylene-butene-1 copolymer of melt index 0.5.

Composition 1 - PP/PP/PP (for comparison)

The use of a "homogeneous" coextrudate as the control was simply an attempt to normalize for any effects of the coextrusion process per se on extensibility. Preheat roll temperatures up to 155 °C were employed briefly, but 130 °C was applied throughout most of the trial. No optimum was established for monolithic PP sheet. Several MDO (machine direction orienter) roll temperatures were evaluated with a short draw gap (5 mm). The best draw roll temperature found for a single stage of drawing in the first draw roll pair was 140 °C. In this condition the maximum draw ratio attained was 9.6. Backing down to 8:1 in MDO-1 gave smooth operation at MDO-2 draw ratios of 1.2-1.3:1 for total draw ratios of 9.6:1-10.4:1 short or long (100 mm) draw gaps gave similar results.

When a third stage of machine direction drawing was applied by continuously heating the web from MDO-2 in the TDO-1 oven (tranverse direction

orienter) at 130 °C while stretching with the pull rolls at the end of the oven, a total stretch ratio of 11.4:1 was achieved at a line speed of 21 meters/min. before break was experienced during the next upward rate adjustment.

Composition 2 - PB/PP/PB.

With this composition, both lower preheat and draw roll temperatures, 130 and 140 °C, respectively, were required to prevent sticking of the PB cap to the rolls. The teflon-coated preheat rolls worked extremely well with the PB. The TDO-1 oven was again run at 130 °C. A long draw gap was employed. The PB/PP/PB was drawn 8:1 in MDO-1, 1.1:1 in MDO-2, and 1.56:1 in TDO-1 for a total draw ratio of 13.9. A line speed of 27.9 meters/min was sustained in this condition. With an auxiliary IR heater on the target draw ratio (15.2:1) and line speed (30.4 meters/min.) were achieved. The drawn laminate produced at this high draw ratio had a tensile strength above 350 MPa, a 1% secant modulus above 10.5 GPa and an elongation at break of less than 10%.

Claims

1. A drawn polyolefin laminate having a tensile strength of at least 0.35 GPa, a 1% secant modulus of at least 10.5 GPa and an elongation at break of less than 10%, and comprising

a) a core layer of a polymer selected from the group consisting of polypropylene and linear low density polyethylene and on each side thereof;

b) a coextruded cap layer of a polymer selected from the group consisting of butene-1 homopolymers and copolymers thereof with ethylene, the laminate having been stretched to a draw ratio of at least 15:1.

2. The laminate of claim 1 wherein the cap layers comprise from about 10 to about 20% of the thickness of the composite.